AD-A182 935   PARALLEL AND DISTRIBUTED COMPUTING(U) MATHEMATICAL   1/1
              SCIENCES RESEARCH INST BERKELEY CA   I KAPLANSKY ET AL
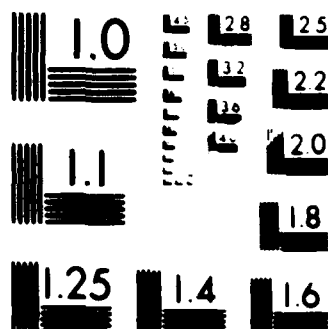   11 DEC 86 AFOSR-TR-87-0899 AFOSR-85-0203

UNCLASSIFIED   F/G 12/5   NL

FND
8-87
DTIC

②

AD-A182 935

SECURITY CLASSIFICATION OF THIS PAGE

RE

DTIC SELECTED JUL 21 1987 D

1a. REPORT SECURITY CLASSIFICATION		
Unclassified		

2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	Approved for public release Distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
	AFOSR-TR- 87-0899

6a. NAME OF PERFORMING ORGANIZATION	6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
Mathematical Sciences Research Institute		AFOSR/NM

6c. ADDRESS (City, State and ZIP Code)	7b. ADDRESS (City, State and ZIP Code)
1000 Centennial Drive Berkeley, CA 94720	Building 410 Bolling AFB, D.C. 20032

8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
AFOSR/M		AFOSR-85-C203

8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS			
Building 410 Bolling AFB, D.C. 20332	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT NO
	61102F 2304/A2 2304/A1	2304	A2	

11. TITLE (Include Security Classification)
Parallel and Distributed Computing

12. PERSONAL AUTHOR(S)
Dr. I. Kaplansky, Dr. R.M. Karp

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final Scientific	FROM 6/1/85 TO 11/30/86	December 11, 1986	16

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB GR	

18. ABSTRACT (Continue on reverse if necessary and identify by block number)

The Berkeley Mathematical Sciences Research Institute (MSRI) featured a program in computational complexity during 1985-86. A substantial part of the program was devoted to parallel and distributed computing. Support for this part of the program was obtained from the present Air Force grant and a similar contract from the Army. Senior personnel supported were Richard Karp and Michael Rabin; Richard Anderson was a postdoctoral fellow. L. M. Auslander and Nathan Linial visited for a month. A workshop on parallel and distributed computing was held from May 19 to May 23, 1986 and drew 40 participants.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS ☐	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
Captain John P. Thomas, Jr.	(202) 767-5025	NM

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE   Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

Final Scientific Report to the Air Force Office of
Scientific Research on Grant AFOSR-85-0203.

CONTENTS

Attachments

Poster for the workshop.
List of participants.
Program of the workshop.
Form 1473.

Final Scientific Report to the U.S. Air Force Office of
Scientific Research on Grant AFOSR-85-0203.

1. Summary. This contract was entitled "Parallel and
distributed computing". It provided $92,000 in partial
support of the yearlong program on Computational Complexity
held at the Berkeley Mathematical Sciences Research Institute
during 1985-86. This was combined with a similar contract
from the Army Research Office and with funding of MSRI from
the National Science Foundation to budget the total program on
Computational Complexity at approximately $600,000.

Intially, the co-principal investigators were
Richard Karp and Calvin Moore. When, on July 1, 1985,
Professor Moore left his post as Deputy Director of MSRI to
become a Vice-President of the University of California
system, Irving Kaplansky (the current Director of MSRI)
replaced him. Professor Karp provided the scientific
direction and Professor Kaplansky the administrative support.

Richard Anderson was a postdoctor fellow supported by the
grant. There was partial support for Richard Karp and, in
addition Michael Rabin of Hebrew University and Harvard
University was a senior visitor for six months (January
through June, 1986). Louis Auslander and Nathan Linial
visited for a month each.

From May 19 to May 23, 1986 MSRI hosted a Workshop
on Parallel and Distributed Computing, supported by the Army
contract and the Air Force grant.

2. Report on the Scientific Work.

Michael Rabin

Rabin worked on a set of algorithms using randomiztion
for control and load sharing in parallel computers. These
algorithms are a substitute for costly hardware solutions,
such as combining networks, for the same problem. The results
will appear in the following paper:

Amos Israeli and Michael Rabin, "Distributed Queues and
Priority Trees for Control in Parallel Computers", to appear.

Richard Karp

Karp investigated parallel algorithms for backtrack search, branch-and-bound computations, and the evaluation of game trees. An outgrowth of this work was an interesting sequential algorithm for conducting a branch-and-bound search within limited storage. He also worked on the probabilistic analysis of combinatorial algorithms, with particular emphasis on bin packing problems. The following papers resulted from this work.

R.M. Karp, M. Saks and A. Wigderson, "A Search Problem Related to Branch-and-Bound Procedures", Proceedings of 27th IEEE Symposium on Foundations of Computer Science, pp. 19-28 (1986).

S. Floyd and R.M. Karp, FFD Bin Packing for Item Sizes with Distributions on [0,1/2]. Proceedings of 27th IEEE Symposium on Foundations of Computer Science, pp. 322-339 (1986).

Richard Anderson

In a joint paper with Alok Agarwal, Anderson settled a major open problem in the theory of parallel computation by showing that the problem of conducting a depth-first-search tree in a directed graph lies in the complexity class Random NC.

A. Agarwal and R. Anderson, "Depth-First Search is in Random NC", to appear.

Nathan Linial

In the paper cited below, it is proved that a graph is k-connected if and only, for every set S of k vertices, it is possible to place the vertices of S at the corners of a (k-1)-dimensional simplex, and the remaining vertices at distinct points in the interior of the simplex, so that, for each vertex v not in S., the interior point corresponding to v lies within the convex hull of the points corresponding to the neighbors of v in the graph. This characterization leads to an efficient randomized algorithm for computing the connectivity of a graph.

N. Linial, L. Lovasz and A. Wigderson, "A Physical
Interpretation of Graph Connectivity, and its Algorithmic
Applications", Proceedings, 27th IEEE Symposium on Foundations
of Computer Science, pp. 39-48, 1986.

Louis Auslander

Louis Auslander studied algorithms for computing large
finite Fourier transforms. There exists an algorithm due to
Cooley and Tukey that is reasonably efficient. However, if
the Fourier transform in question admits a crystallographic
group of transformations, Auslander has divised an improved
method that takes advantage of this. When tried out for a
special case where the group had order 3, it was six times as
fast as the Cooley-Tukey method.

Preparation of a manuscript is in progress, tentatively
titled, "Fourier transforms that respect crystallographic
groups". It will probably be submitted to a journal
specializing in crystallography.

3. Report on the Workshop.

A workshop on the complexity of parallel and
distributed computation was held at MSRI from May 19 to May
23, 1986. The workshop had 21 speakers and 141 participants;
their interests ranged from practical questions about the
architecture of parallel and distributed systems to highly
theoretical questions about the complexity of parallel
computation. A panel discussion was held on the topic
"Bridging the Gap Between the Theory and Practice of Parallel
and Distributed Computing".

The main focus of the workshop was a set of mathematical
and algorithmic issues that underlie the efficient use of the
massively parallel computers that are just beginning to come
into use. Several of the lectures were concerned with
efficient algorithms for such computers. Other lectures were
concerned with the problems of synchronization, load-sharing,
and communication between processors in such systems. A third
major theme was the reliable operation of such systems in the
presence of faulty processors.

The total budget for the workshop was $18,000, of which $15,150 came from the Air Force grant and $2,850 from the Army contract.

The participants supported by the Air Force grant were as follows:

1.	Faith Fich	$ 350.00
2.	Zvi Galil	800.00
3.	Max Garzon	350.00
4.	Andrew Goldberg	350.00
5.	Joe Halpern	300.00
6.	Amos Israeli	350.00
7.	Erich Kaltofen	350.00
8.	Paris Kanellakis	350.00
9.	Simon Kasif	350.00
10.	Sam M. Kim	350.00
11.	Dexter Kozen	650.00
12.	Gad M. Landau	350.00
13.	Jan Karel Lenstra	350.00
14.	Franklin Luk	650.00
15.	Wolfgang Maass	350.00
16.	Silvio Micali	650.00
17.	Gary Miller	400.00
18.	Victor Pan	650.00
19.	Haesun Park	300.00
20.	Alex Pothen	350.00
21.	Vijaya Ramachandran	350.00
22.	Walter L. Ruzzo	250.00
23.	Carla Savage	350.00
24.	J.P. Schmidt	350.00
25.	D.D. Sherlekar	350.00
26.	Alan Siegel	300.00
27.	G.W. Stewart	650.00
28.	Eli Upfal	300.00
29.	Vijay Vazirani	350.00
30.	H. Venkatewaran	250.00
31.	Uzi Vishkin	1,100.00
32.	Paul Vitanyi	350.00
33.	Joachim Von Zur Gathen	300.00
34.	Wei Young	350.00
35.	Moti Yung	350.00

$15,150.00

Workshop on
PARALLEL AND DISTRIBUTED COMPUTATION
May 19-23, 1986
at the
MATHEMATICAL SCIENCES RESEARCH INSTITUTE
BERKELEY, CALIFORNIA

As part of its yearlong 1985-86 program on Computational Complexity, the Mathematical Sciences Research Institute will host a one-week workshop on the complexity of parallel and distributed computation, May 19-23, 1986. The organizing committee consists of R.M. Karp (chairman), H.T. Kung, Michael Rabin, and J.T. Schwartz. One of the principal aims of the workshop is to bring mathematicians and computer scientists working on the theoretical aspects of these subjects into contact with numerical analysts and computer architects involved in the design and use of parallel and distributed computer systems. Major topics addressed at the workshop will include. complexity of parallel computation, combinatorial and numerical parallel algorithms, realization of parallel algorithms in hardware, abstract models of parallel computation, architecture of parallel computers. concurrency control. randomization in parallel and distributed computing. routing algorithms. and fault-tolerant computation in distributed systems.

In addition to the program committee. the following have been invited to participate:

R. Anderson	D. Hillis	E. Mavr	L. Synder
B. Awerbuch	E. Kaltofen	G. Miller	G.W. Stewart
A. Borodin	R. Kannan	C. Moler	L. Stockmeyer
T. Chan	D. Kozen	K. Mulmuley	H. Stone
A. Chandra	D. Kuck	J. Oliger	R. Strong
M. Chandy	R. Ladner	V. Pan	R. Tarjan
R. DeMillo	L. Lamport	C. Papadimitriou	C. Thompson
C. Dwork	E. Lawler	G. Pfister	J. Ullman
P. Dymond	F.T. Leighton	N. Pippenger	E. Upfal
F. Fich	C. Leiserson	F. Preparata	L. Valiant
M. Fischer	R. Lipton	J. Reif	U. Vazirani
Z. Galil	M. Luby	W. Ruzzo	V. Vazirani
J. von zur Gathen	F. Luk	C. Seitz	U. Vishkin
W.M. Gentleman	N. Lynch	D. Shmoys	A. Wigderson
J Halpern	G. Mago	M. Sipser	A. Yao

The workshop will be held at the Institute's new building at 1000 Centennial Drive. Shuttle bus service will be provided from the central campus area.

The mathematical sciences community is warmly invited to attend Additional, more detailed information will be sent to people indicating a desire to come to the workshop. There will be a limited amount of money available to provide partial support for people wishing to attend and participate. New and recent Ph.D.'s are encouraged to apply. Requests for financial support should be received by April 1, 1986. Address inquiries concerning the workshop to *Program Committee. Parallel and Distributed Computing. Mathematical Sciences Research Institute. 1000 Centennial Drive. Berkeley. California 94720* Funding for the conference is provided by the Army Research Office and the Air Force Office of Scientific Research. in cooperation with the Office of Naval Research.

Please Post

COMPLEXITY ASPECTS OF PARALLEL AND
DISTRIBUTED COMPUTING

May 19-23, 1986

Participant List

Selim Akl	Queen's University, SRI, UC Berkeley
Richard Anderson	MSRI
Baruch Awerbuch	MIT
Sara Baase	UC Berkeley
Donald Beaver	Harvard
Marshall Bern	UC Berkeley
Gianfranco Bilardi	Cornell
Adam Bojanczyk	Washington University
Michael Campbell	UC Los Angeles
Larry Carter	UC Berkeley & IBM
Tony Chan	Yale, RIACS
Chandran	University of Maryland
Paul Chew	Dartmouth
Mo-suk Chow	Northeastern University
D. Coan	Floating Point Systems
Richard Cole	NYU
Harold Cox	
Narsingh Deo	Washington State University
Alvin Despain	UC Berkeley
Randall Dougherty	CALTECH
Cynthia Dwork	IBM
Jeanne Ferrante	UC Berkeley & IBM
Faith Fich	University of Washington

COMPLEXITY ASPECTS OF PARALLEL AND DISTRIBUTED COMPUTING

May 19-23, 1986

Participant List

Sally Floyd	UC Berkeley
Lance Fortnow	UC Berkeley
Zvi Galil	Columbia, Tel-Aviv Univ.
Max Garzon	MSU
Phil Gibbons	UC Berkeley
Andrew Goldberg	MIT
Shafi Goldwasser	MIT
P.S. Gopalakrishnan	University of Maryland
Stuart Haber	Columbia
Ramsey Haddad	Stanford
Joe Halpern	IBM
Lisa Hellerstein	UC Berkeley
David Helmbold	Stanford
L. Higham	University of British Columbia
Russell Hinds	UC Berkeley
Dorit Hochbaum	MSRI & UC Berkeley
Joan Hutchinson	Smith College
Amos Israeli	Harvard
Erich Kaltofen	Rensselaer Polytechnic Inst.
Paris Kanellakis	Brown University
Richard Karp	MSRI
Simon Kasif	Johns Hopkins
Zvi Kedem	Courant
Sam Kim	Rensselaer Polytechnic Inst.

COMPLEXITY ASPECTS OF PARALLEL AND DISTRIBUTED COMPUTING

May 19-23, 1986

Participant List

Valerie King	UC Berkeley
Richard King	Kestrel
Philip Klein	MIT
Dexter Kozen	Cornell
Mark Krentel	Cornell
Danny Krizane	Harvard
Richard Ladner	MSRI & University of Washington
Gad Landau	Tel Aviv University
Charles Leiserson	MIT
Jan Karel Lenstra	CWI, Amsterdam
Nick Littlestone	UC Santa Cruz
Laszlo Lovasz	MSRI
Anna Lubiw	UC Berkeley
Michael Luby	University of Toronto
George Lueker	UC Irvine
Frank Luk	Cornell
Stephen Lundstrom	MCC
Wolfgang Maass	University of Illinois, Chicago
Yoni Malachi	IBM Almaden
Michael Matsko	UC Berkeley
Jill Mesirov	Thinking Machines Corp.
Silvio Micali	MIT
Zevi Miller	UC Berkeley
Gary Miller	USC

COMPLEXITY ASPECTS OF PARALLEL AND DISTRIBUTED COMPUTING

May 19-23, 1986

Participant List

Ketan Mulmuley	UC Berkeley
Simeon Naor	UC Berkeley
Lena Nekluobova	Thinking Machines Corp.
Mark Newman	MIT
Noam Nisan	UC Berkeley
Frank Olken	Lawrence Berkeley Lab.
Victor Pan	SUNY Albany
Haesun Park	Cornell
Ramamohan Patiu	Harvard
David Peleg	IBM San Jose
Nicholas Pippenger	IBM Almaden
Carl Ponder	UC Berkeley
Alex Pothen	Pennsylvania State
Harry Printz	CMU
Michael Rabin	Harvard, Hebrew Univ., MSRI
S. Rajasekaran	Harvard
Vijaya Ramachandran	University of Illinois, Urbana
John Reif	Harvard, MSRI
Ronitt Rubinfeld	UC Berkeley
Vlad Rutenburg	Stanford
Larry Ruzzo	Washington
Gary Sabot	Harvard
Miklos Santha	UC Berkeley
Uwek Sarkar	Stanford

COMPLEXITY ASPECTS OF PARALLEL AND
DISTRIBUTED COMPUTING

May 19-23, 1986

Participant List

Carla Savage	North Carolina State
Cathy Schevon	Brown University
J. Schmidt	NYU
Rob Schreiber	Rensselaer Polytechnic Inst.
Ed Schweichel	San Jose State University
Charles Seitz	CALTECH
Amitabm Shah	Cornell
Deepak Sherlekar	University of Maryland
David Shmcys	MIT & MSRI
Alan Siegel	NYU
Janos Simon	University of Chicago
Barbara Simons	IBM San Jose
Michael Sipser	MSRI
Bruce Smith	
Rob Smith	MCC
L. Snyder	University of Washington
Danny Soroker	UC Berkeley
Helmut Stern	UC Berkeley
G.W. Stewart	University of Maryland
Larry Stockmeyer	IBM Almaden
Leen Stougie	UC Berkeley
Charle Swart	Oregon State University
Eva Tardos	MSRI
Robert Tarjan	Princeton & AT&T Bell Labs.

COMPLEXITY ASPECTS OF PARALLEL AND
DISTRIBUTED COMPUTING

May 19-23, 1986

Participant List

Al Thaler	NSF
Athanasios Tsantilas	Harvard
Gyorgy Turan	University of Illinois, Chicago
Jeffrey Ullman	Stanford
Eli Upfal	IBM Almaden
Leslie Valiant	Harvard, MSRI
Umesh Vazirani	MSRI
H. Venkatewaran	University of Washington
Uzi Vishkin	Tel Aviv University
Paul Vitanyi	MIT
Jeff Vitter	MSRI, Brown Univ.
Joachim Von zur Gathen	University of Toronto
John Walker	Stanford
Greg Wasilkowski	Columbia
Avi Wigderson	MSRI
David Wolfe	UC Berkeley
Richard Wongkew	UC Berkeley
Henryk Wozniakowski	Columbia
Mihaly Yeveb	
Wei Young	University of Alabama
Moti Yung	Columbia
Yanjun Zhang	UC Berkeley

MATHEMATICAL SCIENCES RESEARCH INSTITUTE

WORKSHOP ON
COMPLEXITY OF PARALLEL & DISTRIBUTED COMPUTATION
May 19-23, 1986

(All sessions will be held in the MSRI Lecture Hall.)

Monday, May 19

8:30 - 9:30	Arrival of Participants
9:30 - 9:40	Opening of the Workshop
9:40 - 10:30	Richard Anderson, MSRI A Random NC Algorithm for Depth-First Search
10:40 - 11:30	Uzi Vishkin, Tel Aviv University On Methods for Designing Parallel Algorithms
12:30 - 2:00	Lunch Break
2:00 - 2:50	John Reif, Harvard University and MSRI Efficient Parallel Algorithms - Theory and Practice
3:15 - 4:00	Tea
4:00 - 4:50	Gary Miller, University of Southern California Workload Balancing in the Design of Processor- Efficient Parallel Algorithms

Tuesday, May 20

9:00 - 9:50	Gianfranco Bilardi, Cornell University Bitonic Sorting in $O(\log^2 n)$ Time with $O(n/\log n)$ Processors
10:00 - 10:50	Nicholas Pippenger, IBM Almaden Research Center Parallel Comparison Problems
10:50 - 11:30	Coffee Break
11:30 - 12:20	Ketan Mulmuley, University of California at Berkeley Parallel Computation in Linear Algebra
12:20 - 2:00	Lunch Break
2:00 - 2:50	Franklin Luk, Cornell University Parallel Algorithms for Signal Processing
3:15 - 4:00	Tea
4:00 - 4:50	Gilbert Stewart, University of Maryland Determinacy - Its Uses and Limitations
6:30 -	Heyns Room, Faculty Club Reception for all participants

page 2

Wednesday, May 21

9:00 - 9:50	Baruch Awerbuch, MIT Optimal Dynamic Deadlock Resolution Protocols
10:00 - 10:50	Joseph Halpern, IBM Almaden Research Center Analyzing Distributed Systems via Knowledge
10:50 - 11:30	Coffee Break
11:30 - 12:20	Silvio Micali, MIT How to Compile Protocols for Reliable Players to Equivalent Fault-Tolerant Protocols
12:20 - 2:00	Lunch Break
2:00 - 2:50	Eli Upfal, IBM Almaden Research Center On the Relation Between Desirable and Feasible Models for Parallel Computation
3:15 - 4:00	Tea
4:00 - 4:50	Michael Rabin, Harvard University, Hebrew University, and MSRI Randomized Synchronization Primitives for Parallel Computers

Thursday, May 22

9:00 - 9:50	Larry Snyder, University of Washington Type Architectures
10:00 - 10:50	Charles Seitz, California Institute of Technology Low Latency Message-Passing Techniques for Concurrent Computers
10:50 - 11:30	Coffee Break
11:30 - 12:20	Charles Leiserson, MIT VLSI Theory and its Relation to Parallel Supercomputing
12:20 - 2:00	Lunch Break

Thursday, May 22 continued

2:00 - 3:15	Panel Discussion: Closing the Gap Between the Theory and Practice of Parallel and Distributed Computation

Richard Karp, University of California at Berkeley
                    and MSRI
Charles Leiserson, MIT
Michael Rabin, Hebrew University, Harvard University,
                    and MSRI
Charles Seitz, California Institute of Technology
Larry Snyder, University of Washington

3:15 - 4:00	Tea
4:00 - 5:00	Continuation of Panel Discussion

Friday, May 23

9:00 - 9:50	Avi Wigderson, MSRI Lower Bounds in Parallel Computation
10:00 - 10:50	Jeffrey Ullman, Stanford University Parallel Complexity of Logic Programs
11:00 - 11:50	Leslie Valiant, Harvard University and MSRI Learning Algorithms for Connectionist Models

END OF WORKSHOP

PLEASE POST

END

8-87

DTIC